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Nuclear energy consumption, commercial energy consumption and economic growth in South Asia: Bootstrap panel causality test

Ghulam Akhmat [a,*], Khalid Zaman [b,1]

[a] College of Public Administration, Huazhong University of Science and Technology (HUST), 1037 Luoyu Road, Wuhan, PR China
[b] Department of Management Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan

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ABSTRACT

The objective of the study is to investigate the causal relationship among nuclear energy consumption, commercial energy consumption (i.e., oil consumption, gas consumption, electricity consumption and coal consumption) and economic growth in South Asian countries; namely, Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka; over the period of 1975 to 2010. Data is analyzed by bootstrap panel Granger causality method. The results reveal that nuclear energy consumption Granger causes economic growth in Nepal and Pakistan; while, commercial energy consumption i.e., oil consumption Granger causes economic growth in Bangladesh, Bhutan, Maldives, Nepal and Srilanka; gas consumption Granger causes economic growth in Bangladesh, Bhutan, India and Maldives; electricity consumption Granger causes economic growth in India and Srilanka, finally, coal consumption Granger causes economic growth in Bangladesh, Bhutan, Nepal and Srilanka. On the other side, economic growth Granger causes nuclear energy consumption in Pakistan; economic growth Granger causes oil consumption in Bhutan, Maldives and Srilanka; economic growth Granger causes gas consumption in Nepal, Srilanka and Pakistan; finally, economic growth Granger causes electricity consumption. Economic growth Granger causes coal consumption in all South Asian countries. The findings show that the nature of causality between nuclear energy consumption & economic growth; and commercial energy consumption & economic growth is in favor of the neutrality hypothesis in most of the countries.

Contents

1. Introduction

South Asia is home to well over one fifth of the world's population, making it both the most populous and the most densely populated geographical region in the world. Southern Asia comprises the countries of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The South Asian Association for Regional Cooperation (SAARC) is an economic cooperation organization in the region [22]. Global energy demand continues to increase rapidly, driven by growing demand in the U.S. and expanding economies in China, India, and other countries in Asia. Coupled with soaring prices for crude and the political uncertainties in many oil-producing countries, energy users, especially those in South Asia, face a difficult future in meeting their long-term energy needs [50]. South Asia is a region of stark contrasts. One of the most populous regions of the world, it has a

* Corresponding author. Tel.: +86-15827481835; fax: 0086-27-87543047
E-mail addresses: ahmad_choudary@hotmail.com (G. Akhmat), khalidzaman@ciit.net.pk (K. Zaman).
[1] Tel.: +92 334 8982744; fax: +92 992 383441.

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relatively small land mass and a high incidence of poverty. The countries of the region range in size from India, with a population of over 1 billion, to the Maldives with a population of just 340,000. The per capita GNP ranges from over $1800 in the Maldives to less than $186 in Afghanistan [47].

In South Asia, India has an ambitious nuclear energy plans. From approximately 4800 MWe currently, Department of Atomic Energy (DAE) plans to add 30,000 MWe by 2020 and 60,000 MWe by 2032. Pakistan has announced that its nuclear energy target is to achieve an installed capacity of 8800 MW by 2030 from 462 MW as of today [1]. In 2001, Bangladesh adopted a National Nuclear Power Action Plan. At present, 2 units of 1000 MW each have been proposed in Ruppur in Pabna District around 50 km/s from Indian boarder [20].

Government of Sri Lanka has given its clearance to set up a nuclear power plant of 1000 MW, and has submitted a request to the International Atomic Energy Agency for a pre-feasibility study. Nepal does not have any short term nuclear energy plans. However, the National Nuclear Policy adopted in 2008, recognizes the great importance of application of nuclear energy/technology in the development process of Nepal. Afghanistan, Bhutan and Maldives currently do not have any plans to develop nuclear energy programs [29]. Table 1 shows comparative pictures of energy dependency in South Asian countries.

Deficiency in energy sector is a major problem, which can hinder the development workflow of any country. Being the eighth most populated country in the world with a total electricity generation of only about 5000 MW and consumption of 144 kW h per capita, Bangladesh is one of the most electricity-deprived countries around the globe. In addition, absence of adequate investment and mass people awareness is a major problem in this country [48]. Therefore, it would be very difficult to achieve overall progress without ensuring energy security by utilizing the promising renewable energy sources [39].

The Integrated Nepal Power System (INPS) has a total installed capacity of 706 MW of which 652 MW (92%) is generated from hydro resources. The annual electricity generation on the grid system in 2009–2010 was about 3690 GW h, of which power plants owned by the Nepal Electricity Authority (NEA), 26% by IPPs, generated about 57% and the remaining 17% was imported from the Indian grid [19].

Pakistan Atomic Energy Commission (PAEC) is responsible for planning, construction and operation of nuclear power plants in the country. PAEC is currently operating three nuclear power plants i.e. Karachi Nuclear Power Plant (KANUPP) and Chashma Nuclear Power Plant Unit-1 and 2 (C-1 and C-2). The construction of two more units C-3 and C-4 of being 340 MW each is in progress [13].

Bhutan Power Corporation (BPC), responsible for domestic power supply, and Druk Green Power Company (DGPC), responsible for operating the export-oriented hydropower projects, has been profitable. Bhutan has committed to an ambitious agenda of developing over 10,000 MW (MW) of hydropower capacity by 2020 with assistance from the Government of India, and achieving 100% electrification by 2013 (ADB, 2010).

Table 1
Energy dependence of South Asian countries.

Country	Source of energy	Dependence
Bangladesh	Natural gas	86%
India	Coal and petroleum & gas	Coal-56%, P & G-35%
Srilanka	Hydro and petroleum & gas	Hydro-50%, P & G-46%
Maldives	Petroleum	100%
Nepal & Bhutan	Hydro	96%
Pakistan	Petroleum & gas, hydro	P&G-66%, hydro −33%

Source: Mahapatra [27].

Sri Lanka has total identified major hydro power potential of 2006 MW out of which 1207 MW is harnessed as at present. One 150 MW Upper Kotmale hydro power project is under construction and scheduled to commission in 2011. 300 MW privately owned Combined Cycle Power Plant operating on furnace oil at Kerawalapitiya is under construction. Full operation of that power plant is expected in 2009. The mini hydro potential is identified as 200 MW out of which 110 MW has already been developed in Srilanka [5].

Geographically, Maldives is one of the most vulnerable nations to the effects of climate change impacts such as sea level rise [49]. The Energy Authority of Maldives has announced the inception of $138 million renewable energy project which would generate 26 MW of electricity in Maldives [23].

Currently, India is one of the world's fastest-growing economies. During the period between 2006 and 2010, the country's gross domestic product (GDP) increased at an 8.2%, while global GDP increased at a 4.5%. The rapid increase in economic activity has been accompanied by rising energy consumption. During the period of 2006 and 2010, India's primary energy consumption increased at 8.3% from 381.4 million tons of oil equivalent (MTOE) to 524.2 MTOE. Coal, oil and natural gas are major sources of primary energy of India, accounting for 52.9%, 29.6% and 10.6%, respectively, of the primary energy consumption [12].

Determining the direction of causality between energy consumption and economic growth provides important inferences in establishing sound energy policies. A vast literature thereby has been documented on casual relationships between economic growth and consumption of energy sources (electricity, coal, natural gas, and oil) in last two decades ([32]; and [33]). The empirical literature has now been focusing on examining the nature of causality between nuclear energy consumption and economic growth due to the fact that nuclear energy is an important source for increasing diversity of energy supplies, for improving energy security, and for providing a low-carbon alternative to fossil fuels [52].

Nazlioglu et al. [30] determine the direction causality between nuclear energy consumption and economic growth in fourteen OECD countries during the period 1980–2007. The findings show that there is no causality between nuclear energy consumption and economic growth in eleven out of fourteen cases, supporting the neutrality hypothesis. Lee and Chiu [26] applies panel data analysis to examine the short-run dynamics and long-run equilibrium relationships among nuclear energy consumption, oil prices, oil consumption, and economic growth for developed countries covering the period 1971–2006. The panel causality results find evidence of unidirectional causality running from oil prices and economic growth to nuclear energy consumption in the long run, while there is no causality between nuclear energy consumption and economic growth in the short run. Wolde-Rufael and Menyah [52] test the causal relationship between nuclear energy consumption and real GDP for nine developed countries for the period 1971–2005. The result found a unidirectional causality running from nuclear energy consumption to economic growth in Japan, Netherlands and Switzerland; the opposite unidirectional causality running from economic growth to nuclear energy consumption in Canada and Sweden; and a bi-directional causality running between economic growth and nuclear energy consumption in France, Spain, the United Kingdom and the United States.

[35] examines the relationship between nuclear energy consumption growth and real gross domestic product (GDP) growth for the US using annual data from 1957 to 2006. The long-run Granger-causality reveals the absence of Granger-causality between nuclear energy consumption growth and real GDP growth which supports the neutrality hypothesis within the energy consumption–economic growth literature. Pradhan [38] explores the nexus between energy

consumption (oil and electricity) and economic growth in the five SAARC countries over the period 1970–2006. The study finds a unidirectional short run and long run causality from oil consumption to economic growth in Bangladesh and Nepal, a unidirectional short run and long run causality from electricity consumption to economic growth in Pakistan and Sri Lanka, a unidirectional short run and long run causality from economic growth to oil consumption in India and Sri Lanka, and a unidirectional causality from economic growth to electricity consumption in India and Nepal. It also finds the bidirectional causality between electricity consumption and economic growth in Bangladesh and between oil consumption and economic growth in Pakistan. Apergis and Payne [4] examine the relationship between nuclear energy consumption and economic growth for sixteen countries within a multivariate panel framework over the period 1980–2005. The results find bidirectional causality between nuclear energy consumption and economic growth in the short-run while unidirectional causality from nuclear energy consumption to economic growth in the long-run. Balcilar et al. [7] analyzes the causal links between energy consumption and economic growth for G-7 countries using bootstrap Granger non-causality tests with fixed size rolling sub-samples over a period of 1960–2006. The results indicate no consistent causal links between energy consumption and economic growth, however, find that causal links are present between the series in various sub-samples. Payne [34] provides a disaggregated analysis of the causal relationship between fossil fuel consumption and real gross domestic product (GDP) in the US using annual data from 1949 to 2006. The long-run causality tests reveal the absence of Granger-causality between coal consumption and real GDP; positive unidirectional causality from real GDP to natural gas consumption; and positive unidirectional causality from petroleum consumption to real GDP. Wolde-Rufael [51] tests the causal relationship between nuclear energy consumption and real gross domestic product for Taiwan for the period 1977–2007. The result finds no causality running in any direction between economic growth and nuclear energy consumption, which suggested that the neutrality hypothesis is accepted.

Zaman et al. [57] re-investigate the multivariate electricity consumption function for Pakistan over a period of 1975–2010. The results reveal that determinants of electricity consumption function are cointegrated and influx of foreign direct investment, income and population growth is positively related to electricity consumption in Pakistan. Shahbaz et al. [41] investigates the relationship between energy (renewable and nonrenewable) consumption and economic growth in case of Pakistan over the period of 1972–2011. The findings show that both renewable and non-renewable energy consumption add in economic growth. Capital and labor are also important determinants of Pakistan's economic growth.

Shukla and Chaturvedi [43] analyzes a targets approach for pushing solar, wind, and nuclear technologies in the Indian electricity generation sector from 2005 to 2095. The study find that higher cost significantly decreases the share of nuclear power under both the reference and carbon price scenarios. Kumar and Shahbaz [25] examined the liaison between coal consumption and economic growth for Pakistan over the period 1971–2009. The result confirms the long-run relationship between coal consumption and economic growth in Pakistan. Zaman et al. [58] identify major macroeconomic factors that enhance energy consumption for Pakistan over a period of 1980–2011. The result confirms the long-run relationship between total commercial energy consumption and macroeconomic factors in Pakistan. The study finds evident of unidirectional causality between the commercial energy consumption factors and macroeconomic factors in Pakistan. However, there is some bidirectional causality exist which is running between electricity consumption (EC) and exports, EC to imports, EC to carbon emissions, EC to natural resource depletion (NRD) and EC to wheat. Shrestha [42] examine the opportunity for market entry, the demand for renewable energy and the networking between different energy related organizations in Nepal. The finding of this study is that it could be feasible to provide renewable energy services in remote areas because the Government of Nepal is providing subsidy in this area.

Both nuclear energy and other forms of energy in relation with growth, discussed widely in the domain of energy literature, hence there is a pressing need to evaluate and analyze this phenomenon in South Asian countries. To understand the dynamics of the energy policy framework governing South Asia's energy sector, it is essential to comprehend the policy objectives and context in which they are placed.

The objective of the study is to investigate the relationship between energy consumption (using both nuclear energy consumption and total primary energy consumption) and economic growth in South Asian countries by using bootstrap panel Granger causality method over a period of 1975–2010. The more specific objectives are:

I. Whether the statistical relationship between the energy consumption indicators and economic growth of South Asian countries are unidirectional (i.e., energy consumption indicators affect/cause economic growth or growth affect/cause energy indicators);
II. Whether the statistical relationship between the energy consumption indicators and economic growth of South Asian countries are bidirectional (i.e., energy consumption indicators affect/cause economic growth and growth affect/cause energy indicators);
III. The two variables (energy and growth) do not influence each other (causality independent).

The plan of this study is organized as follows: after introduction which is presented in Section 1 above, Section 2 shows the data source and econometric methods, Section 3 presents empirical results and final Section concludes the study.

2. Data source and methodological framework

The annual data used in this study cover the period from 1975 to 2010 for South Asian countries (i.e., Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Srilanka). In this study, there are four commercial energy consumption indicators used i.e., oil consumption (OILC), gas consumption (GC), electricity consumption (EC) and coal consumption (CC) along with nuclear energy consumption per capita (NEC), while real GDP per capita (RGDP) is used for economic conditions of the South Asian countries. Nuclear energy consumption is expressed in terms of Terawatt-hours (TW h), oil consumption is expressed in tonnes, gas consumption is Millimeter Cubic foot (mm cft), electricity consumption is in Kilo Watt per Hour (kW h), coal consumption is expressed in thousand metric tonnes data are obtained from International Energy outlook [17]. Real GDP per capita measured in constant 2000 US dollars comes from World development indicator which is published by World Bank [53]. As, Afghanistan, Bhutan and Maldives currently do not have any plans to develop nuclear energy programs, therefore, these countries excluded from the estimations of nuclear energy consumption and growth nexus. However, for oil consumption, gas consumption, electricity consumption and coal consumption, this study applies for all South Asian countries. All the variables are expressed in natural logarithm in the empirical analysis.

2.1. Methodology

Investigating Granger causality within panel data framework requires a careful treatment. Our empirical analysis starts with testing for cross-sectional dependency, followed by slope homogeneity across countries. The cross-sectional dependency among countries implies that a shock that affects one country may spill on other countries. When we consider South Asian countries, cross-sectional dependency may play crucial role in detecting causal linkages among economic series since countries are highly integrated and have a high degree of globalization.

To test for cross-sectional dependency, Breusch and Pagan [8] proposed a Lagrange test. The construction of the test statistic depends upon the estimation of the following panel data model:

$$y_{it}=\alpha_i+\beta'_i x_{it}+\varepsilon_{it} \text{ for } i=1,2,...,N;\ t=1,2,...,T \tag{1}$$

where i is the cross section dimension, t is the time dimension, y_{it} is the dependent variable x_{it} is $k\times 1$ vector of explanatory variables, α_i and β_i are, respectively, the individual intercepts and slope coefficients that are allowed to vary across countries. For each i, ε_{it} are identically and independently distributed error terms for all t—although they could be cross-sectional correlated. The null hypothesis of no-cross sectional dependency—$H_0:\ Cov(\varepsilon_{it},\varepsilon_{jt})=0$, for all t and $i\neq j$ – is tested against the alternative hypothesis of cross-sectional dependency – $H_1:\ Cov(\varepsilon_{it},\varepsilon_{jt})\neq 0$ for at least one pair of $i\neq j$.

Determining whether slope coefficients are homogeneous or heterogeneous is also important in a panel causality analysis to impose causality restrictions on estimated coefficients. In Eq. (1), the null hypothesis of slope homogeneity—$H_0:\beta_i=\beta$, for all i – is tested against the alternative hypothesis of heterogeneity – $H_1:\beta_i\neq\beta_j$, for a non-zero fraction of pair-wise slopes for $i\neq j$. In order to test for the null hypothesis, the familiar approach is to follow the Wald principle. Accordingly, test of slope homogeneity is $H_0:\beta_1=...=\beta_N$ where the Wald statistic is asymptotically distributed as chi-square with $N-1$ degrees of freedom (see, [28]). The test based on the Wald principle is valid for cases where the cross section dimension (N) is relatively small and the time dimension (T) of panel is large; the explanatory variables are strictly exogenous; and the error variances are homoscedastic [37].

Similar to the Wald principle, Swamy [46] developed the slope homogeneity test on the dispersion of individual slope estimates from a suitable pooled estimator. Even though Swamy's test is valid for panel with fixed N and large T just as the Wald test, it allows for cross-section heteroscedasticity [37]. The Swamy test for slope homogeneity is:

$$S=\sum_{i=1}^{N}(\widehat{\beta}_i-\widehat{\beta}_{WFE})'\frac{x'_iM_\tau x_i}{\widehat{\sigma}_i^2}(\widehat{\beta}_i-\widehat{\beta}_{WFE}) \tag{2}$$

where $\widehat{\beta}_i$ is the pooled OLS estimator, $\widehat{\beta}_{WFE}$ is the weighted fixed effect pooled estimator, $M_\tau=I_T-Z_i(Z'_iZ_i)^{-1}Z'_i$ and $Z_i=(\tau_T,X_i)$, where τ_T is a $T\times 1$ vector of ones, and $\widehat{\sigma}_i^2$ is the estimator of error variance, σ_i^2. In the case where N is fixed and $T\to\infty$, the S test has an asymptotic chi-square distribution with $k(N-1)$ degrees of freedom.[2]

The system to be estimated in the bootstrap panel causality approach can be formulated as follows:

$$\begin{aligned}
y_{1,t}&=\alpha_{1,1}+\sum_{l=1}^{ly_1}\beta_{1,1,l}y_{1,t-l}+\sum_{l=1}^{lx_1}\delta_{1,1,l}x_{1,t-l}+\varepsilon_{1,1,t}\\
y_{2,t}&=\alpha_{1,2}+\sum_{l=1}^{ly_1}\beta_{1,2,l}y_{2,t-l}+\sum_{l=1}^{lx_1}\delta_{1,2,l}x_{2,t-l}+\varepsilon_{1,2,t}\\
&\vdots\\
y_{N,t}&=\alpha_{1,N}+\sum_{l=1}^{ly_1}\beta_{1,N,l}y_{N,t-l}+\sum_{l=1}^{lx_1}\delta_{1,N,l}x_{1,N,t-l}+\varepsilon_{1,N,t}
\end{aligned} \tag{3}$$

and

$$\begin{aligned}
x_{1,t}&=\alpha_{2,1}+\sum_{l=1}^{ly_2}\beta_{2,1,l}y_{1,t-l}+\sum_{l=1}^{lx_2}\delta_{2,1,l}x_{1,t-l}+\varepsilon_{2,1,t}\\
x_{2,t}&=\alpha_{2,2}+\sum_{l=1}^{ly_2}\beta_{2,2,l}y_{2,t-l}+\sum_{l=1}^{lx_2}\delta_{2,2,l}x_{2,t-l}+\varepsilon_{2,2,t}\\
&\vdots\\
x_{N,t}&=\alpha_{2,N}+\sum_{l=1}^{ly_2}\beta_{2,N,l}y_{N,t-l}+\sum_{l=1}^{lx_2}\delta_{2,N,l}x_{N,t-l}+\varepsilon_{2,N,t}
\end{aligned} \tag{4}$$

where y denotes the real income, x refers to the indicators of energy consumption (nuclear energy consumption (NEC), oil energy consumption (OILC), gas consumption (GC), electricity consumption (EC), coal consumption (CC), l is the lag length, ly_1 and lx_1 are the maximal lags for Y and X in the first set of equations, and ly_2 and lx_2 are the maximal lags for Y and X in the second set of equations. Since each equation in this system has different predetermined variables while the error terms might be contemporaneously correlated (i.e., cross-sectional dependency), these sets of equations are the SUR system.

To test for Granger causality in this system, alternative causal relations are likely to be found for a country: (i) there is one-way Granger causality from X to Y if not all $\delta_{1,i}$ are zero, but all $\beta_{2,i}$ are zero, (ii) there is one-way Granger causality running from Y to X if all $\delta_{1,i}$ are zero, but not all $\beta_{2,i}$ are zero, (iii) there is two-way Granger causality between X and Y if neither $\delta_{1,i}$ nor $\beta_{2,i}$ are zero, and (iv) there is no Granger causality between X and Y if all $\delta_{1,i}$ and $\beta_{2,i}$ are zero.

Since the results from the causality test may be sensitive to the lag structure, determining the optimal lag length(s) is crucial for robustness of findings. Thereby, prior to estimation, we have to specify the number of lags. For a relatively large panel, equation and variable with varying lag structure would lead to an increase in the computational burden substantially. To overcome this problem, following Kónya [59] we allow maximal lags to differ across variables, but to be the same across equations. We estimate the system for each possible pair of ly_1, lx_1, ly_2, and lx_2, respectively, by assuming from 1 to 4 lags and then choose the combinations which minimize the Schwarz Bayesian Criterion.

3. Results and discussion

To investigate the existence of cross-sectional dependence, this study is carried out four different tests i.e., LM, CD_{lm}, CD, LM_{adj} which is illustrated results in Table 2.

The result reveals that the null hypothesis of no cross-sectional dependency across the countries is strongly rejected at the conventional levels of significance, implying that the seemingly unrelated regressions (SUR) method is appropriate rather than country-by-country OLS estimation. This finding implies that a shock occurred in one of the South Asian countries seems to be transmitted to other countries. Table 2 also reports the results from the two slope homogeneity tests (Wald and S). Both tests reject the null hypothesis of the slope homogeneity hypothesis, supporting the country specific heterogeneity. The rejection of slope homogeneity implies that the panel causality analysis by imposing homogeneity restriction on the variable of interest results in misleading inferences [9]. In this respect, the panel causality analysis based on estimating a panel vector autoregression and/or panel vector error correction model by means of generalized method of moments and of pooled ordinary least square estimator is not appropriate approach in detecting causal

[2] We refer an interested reader to Pesaran and Yamagata [37] for the details of Swamy's test and its extension for panels where N and T are both large. Since N is small relative to T in our study, we used the Swamy test.

Table 2
Cross sectional dependency and homogeneity tests for energy consumption indicators in South Asian countries.

Study	Test	NEC	OILC	GC	EC	CC
Breusch and Pagan [8]	LM	201.142*	194.512*	219.201*	221.012*	192.521*
[36]	CD_{ml}	38.214*	44.256*	69.301*	32.409*	35.012*
	CD	15.012*	19.288*	13.518*	13.852*	14.041*
[37]	LM_{abj}	61.201*	85.259*	99.012*	57.112*	96.707*
[28]	Wald	117.201*	66.259	109.012*	113.080*	53.489*
Swamy [46]	S	41.021*	85.302*	116.025*	31.885*	116.524*

* Indicates significance at the 0.01 level. For NEC, Bangladesh, India, Nepal, Pakistan and Srilanka are considered for evaluation. However, commercial energy consumption i.e., OILC, GC, EC and CC, all South Asian countries are considered for estimation.

linkages between energy consumption indicators and economic growth in South Asian countries.

The study evidence an existence of the cross-sectional dependency and the heterogeneity across South Asian countries support evidence on the suitability of the bootstrap panel causality approach. The results of one-way Granger causality running from real GDP per capita to energy consumption indicators i.e., nuclear energy consumption, oil consumption, gas consumption, electricity consumption and coal consumption is reported in Table 3.

The results show one-way Granger causality running from economic growth to nuclear energy consumption in India, Nepal and Srilanka at 1 and 5% significance level. However, Bangladesh and Pakistan, the null hypothesis of non- causality running from economic growth to nuclear energy consumption cannot be rejected. The direction of Granger causality running from economic growth to oil consumption in another model, the null hypothesis is rejected in the case of the Bhutan, Maldives and Srilanka at 1 and 5% level of significance. Subsequently, the null hypothesis of non-causality running from economic growth to gas consumption cannot be rejected in Afghanistan, Nepal, Pakistan and Srilanka, however, Bangladesh, Bhutan, India and Maldives reject the null hypothesis of non-causality at 1 and 5% level. In case of electricity and coal consumption, except Afghanistan, all South Asian countries have a casual relationship which is running towards economic growth to electricity and coal consumption.

The results of one-way Granger causality running from energy consumption indicators to real GDP per capita are reported in Table 4.

Regarding energy consumption and growth nexus, we find one-way Granger causality running from nuclear energy consumption to economic growth for Bangladesh, Nepal and Pakistan. Besides, the null hypothesis of nuclear energy consumption is not Granger cause of economic growth is accepted for India and Srilanka. As regards to the direction of oil consumption to economic growth, significant relationship exists in Bangladesh, Bhutan, Maldives, Nepal and Srilanka in which the growth hypothesis holds. In case of gas consumption, Bangladesh, Bhutan, India and Maldives Granger cause economic growth, however, Afghanistan, Nepal, Pakistan and Srilanka, oil consumption led growth hypothesis does not holds. Electricity consumption Granger cause economic growth in India and Srilanka only, while in case of coal consumption in Bangladesh, Bhutan, Nepal, Pakistan and Srilanka, these countries Granger cause economic growth.

The time series approaches overlook cross-sectional dependency across countries in the causality test, and hence they may result in misleading inferences regarding the nature of causality between energy consumption and economic growth [9]. This study finds some strong evidences on the existence of cross-section dependence among South Asian countries, and thereby it might be concluded that the policy implications driven from the causality approach that accounts for cross-sectional dependency seem to be more appropriate. Furthermore, this study also detected cross-country heterogeneity in the panel

Table 3
Causality towards RGDP to energy consumption indicators (NEC, OILC, GC, EC and CC).

South Asian countries	Wald statistics	Bootstrap critical values		
		1%	5%	10%
RGDP does not Granger cause NEC				
Bangladesh	14.124	33.885	21.020	15.001
India	24.852**	28.589	16.582	11.889
Nepal	19.859*	18.147	11.028	7.898
Pakistan	15.110	32.148	22.020	16.841
Srilanka	28.589*	18.014	12.025	8.025
RGDP does not Granger cause OILC				
Afghanistan	0.012	24.852	12.258	8.825
Bangladesh	13.898	31.025	19.025	14.012
Bhutan	17.145**	24.258	12.447	5.528
India	4.898	24.995	14.025	5.012
Maldives	17.565**	24.001	16.852	5.828
Nepal	8.801	17.821	14.258	9.858
Pakistan	0.120	31.258	12.258	5.201
Srilanka	28.859*	17.014	12.025	4.201
RGDP does not Granger cause GC				
Afghanistan	3.582	21.020	16.582	8.258
Bangladesh	12.589**	28.889	11.011	8.258
Bhutan	29.124*	20.102	16.589	9.982
India	28.201*	20.889	14.552	11.012
Maldives	16.012**	21.365	15.258	10.012
Nepal	3.859	16.658	8.285	4.478
Pakistan	4.589	18.952	9.250	6.653
Srilanka	5.782	14.014	8.852	6.012
RGDP does not Granger cause EC				
Afghanistan	0.102	20.012	14.015	3.356
Bangladesh	15.012**	24.845	11.225	6.665
Bhutan	11.148**	19.895	9.852	4.258
India	24.012*	19.012	11.014	5.859
Maldives	29.852*	20.011	15.258	7.884
Nepal	8.012**	15.514	7.778	4.487
Pakistan	15.825**	17.789	11.120	6.602
Srilanka	19.898*	13.001	7.785	6.012
RGDP does not Granger cause CC				
Afghanistan	1.857	15.514	8.825	3.352
Bangladesh	19.898*	17.014	9.989	4.012
Bhutan	27.220*	13.258	7.786	4.110
India	18.201*	13.012	6.689	3.338
Maldives	19.012*	17.856	13.582	3.364
Nepal	11.101**	14.412	8.889	4.458
Pakistan	16.014*	15.258	12.221	7.789
Srilanka	7.896**	11.012	5.589	3.478

Note: * and ** indicates significance at the 0.01 and 0.05% level. For NEC, Bangladesh, India, Nepal, Pakistan and Srilanka are considered for evaluation. However, commercial energy consumption i.e., OILC, GC, EC and CC, all South Asian countries are considered for estimation.

Table 4
Causality towards energy consumption indicators (NEC, OILC, GC, EC and CC) to RGDP.

South Asian countries	Wald statistics	Bootstrap critical values		
		1%	5%	10%
NEC does not Granger cause RGDP				
Bangladesh	24.254**	30.958	20.214	14.285
India	2.245	20.214	9.545	4.124
Nepal	6.668**	17.258	5.258	3.324
Pakistan	19.825*	17.012	5.124	3.012
Srilanka	1.889	17.014	4.998	3.001
OILC does not Granger cause RGDP				
Afghanistan	4.458	23.012	12.012	8.785
Bangladesh	19.254**	28.256	18.584	8.398
Bhutan	13.258**	18.589	8.258	3.985
India	21.2458	18.452	8.147	3.885
Maldives	9.998**	18.114	8.547	3.547
Nepal	17.258*	14.214	4.458	3.324
Pakistan	1.102	14.247	4.578	2.999
Srilanka	11.012**	13.258	4.124	3.001
GC does not Granger cause RGDP				
Afghanistan	1.885	21.248	11.012	7.895
Bangladesh	17.012**	24.857	16.258	6.589
Bhutan	19.012*	16.898	6.589	4.985
India	15.012**	17.452	6.147	4.885
Maldives	8.801**	16.589	7.547	3.547
Nepal	1.458	13.582	5.258	3.324
Pakistan	2.012	13.477	4.578	3.589
Srilanka	1.789	12.258	5.124	3.021
EC does not Granger cause RGDP				
Afghanistan	3.338	19.248	10.282	6.895
Bangladesh	3.485	22.857	8.589	6.582
Bhutan	2.012	15.895	7.589	5.985
India	9.856**	14.358	6.258	5.885
Maldives	0.124	14.589	5.547	3.577
Nepal	2.012	12.582	5.585	3.394
Pakistan	1.102	12.477	4.578	3.579
Srilanka	11.895*	11.458	5.198	3.2581
CC does not Granger cause RGDP				
Afghanistan	2.221	17.214	9.256	5.895
Bangladesh	8.258**	20.857	7.588	5.336
Bhutan	11.012**	14.225	6.223	4.985
India	3.223	13.898	6.012	4.224
Maldives	2.012	13.589	6.589	3.587
Nepal	19.852*	11.582	5.596	3.894
Pakistan	17.256*	11.447	4.278	3.279
Srilanka	15.077*	10.589	4.198	3.058

Note: * and ** indicates significance at the 0.01 and 0.05% level. For NEC, Bangladesh, India, Nepal, Pakistan and Srilanka are considered for evaluation. However, commercial energy consumption i.e., OILC, GC, EC and CC, all South Asian countries are considered for estimation.

of South Asian countries, implying that each country may develop its energy policies [44,3,15].

The bootstrap panel causality approach which takes into account cross-sectional dependency and cross-country heterogeneity indicates that the nature of the causality between the energy consumption indicators and economic growth is in favor of neutrality hypothesis in more of South Asian countries. More specifically, the neutrality hypothesis holds for nuclear energy consumption–economic growth nexus in India and Srilanka, for oil consumption–economic growth nexus in Afghanistan, India and Pakistan, for gas consumption–economic growth nexus in Afghanistan, Nepal, Pakistan and Srilanka, for electricity consumption and economic growth nexus in Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Pakistan and for coal consumption-growth nexus in Afghanistan, India and Maldives.

The direction of causation between energy consumption and economic growth has significant policy implications. As, in case of one-way Granger causality running from nuclear energy consumption to growth in Nepal and Pakistan, it implied that reducing nuclear energy consumption lead to a fall in income. Therefore, environmental policies to conserve nuclear energy consumption may weaken the economic growth and development in countries [6]. On the other hand, one-way Grange causality running from economic growth to nuclear energy consumption in India, Nepal and Srilanka, it implied that nuclear energy conservation policies implemented with little adverse or no effects on economic growth. Similarly, this explanation is hold for others energy consumption indicators i.e., oil consumption, gas consumption, elasticity consumption and coal consumption in South Asian region. The finding of no causality in either direction, the so-called 'neutrality hypothesis' [60] would imply that energy conservation policies do not affect economic growth.

The neutrality between energy consumption indicators and economic growth suggests that energy conservation policies do not exert an adverse impact economic growth and that energy consumption indicators are not affected by economic performance. One can attribute the neutrality between energy consumption (for nuclear, oil, gas, electricity and coal consumption) and economic growth to a relatively small contribution of the energy usage to overall output. Thus, energy consumption indicators may have little or no impact on economic growth. The neutrality between energy use and economic growth also implies that investments in energy reactors and increase of capacity of nuclear energy production which stimulates production do not boost income levels directly [54]. This does not however decrease the importance of nuclear energy in the process of economic development. The production requires employing various kinds of inputs such natural resources, capital, and labor force as well as (nuclear) energy [18]. Moreover, not only environmental but also social concerns provide paying keen interest in nuclear energy use [55], thus policies that are aimed at conserving energy will not retard economic growth in selected South Asian countries [10].

Nuclear electricity generation is virtually free of direct greenhouse gas emissions, but as with any generation technology, ;there are indirect emissions associated with mining, fuel fabrication; construction and decommissioning of the power plant, and disposal of the waste. Some of these activities can be energy intensive, and depending on the carbon footprint of the energy system where this activity takes place, lead to non-negligible emissions of greenhouse gases. Nuclear energy plays an important role in limiting greenhouse gas emissions in the power sector. In 2009, it represented 13.4% of the world electricity production, the second largest low-carbon source behind hydro's 16.4% share [31].

Apparently, our studies are not consistent with those of Shahbaz et al [40], Yoo and Ku [56] and Heo et al. [14]. Shahbaz et al. [40] investigated the relationship between natural gas consumption and economic growth in Pakistan using a multivariate model for the periods of 1972–2009. The result suggests a unidirectional causality running from natural gas consumption to economic growth. Yoo and Ku [56] considered six countries namely, Argentina, France, Germany, Korea, Pakistan, and Switzerland, using nuclear consumption and economic growth data and found unidirectional causality runs from economic growth to nuclear energy consumption without any feedback effects in Pakistan. Heo et al. [14] employed co-integration and error-correction models to test the relationship between nuclear consumption and economic growth in India. They found unidirectional causality running from nuclear energy consumption to economic growth without any feedback effect.

However, our result accords with the findings of others [16,21] both studies have concluded that the neutrality hypothesis for the Pakistan and Srilanka, respectively. Joyeux and Ripple [24] by applying the panel causality analysis which take into account

cross-sectional dependency supported evidence on the neutrality hypothesis in 30 OECD and 26 non-OECD countries. Furthermore, by comparing the results from the panel causality analysis with those from the Toda–Yamamoto time series causality approach, Joyeux and Ripple [24] and Nazlioglu et al. [30] indicated that the choice of statistical method is important in causality analysis.

4. Conclusion and recommendations

Energy consumption per capita is one of the single most important factors in regards to living standards of individuals across the world. Important goals and basic principles of future energy sources include: nuclear energy plant reducing greenhouse gas emissions; minimizing the overall environmental footprint; safety and reliability; sustainability; economics; efficiency, and energy independence. The objective of the study is two fold, on one hand, this study examines the causal links between nuclear energy consumption and economic growth, as the direction of causation of this relationship remains controversial in the existing literature. It also explores the relationship between commercial energy consumption (i.e., oil, gas, electricity and coal consumption) and economic growth in South Asian countries over a period of 1975–2010, by using bootstrap panel Granger causality approach.

The nature of causality between energy consumption and economic growth is identified by conducting a systematic modeling approach. Our study benefit from panel causality approach instead of time series methods since panel analysis produces more reliable and statistically powerful results than time series analysis by combining information from both cross-section and time dimensions. Moreover, we test for cross-sectional dependency and heterogeneity across countries due to the fact that ignoring cross-sectional dependency and country specific heterogeneity in a panel causality analysis are potential sources of misleading inferences regarding the direction of causality. No doubt that South Asian countries have a highly degree of integration and thereby a shock in one country is likely to be transmitted to other countries through international economic interrelationships. This is not done in the previous studies. Our empirical results lead us to conclude that the relationship between energy consumption (for both nuclear consumption and commercial energy indicators) and economic growth cannot be generalized across countries. Since both two slope homogeneity tests (Wald and S) reject the null hypothesis of the slope homogeneity hypothesis, supporting the country specific heterogeneity. Our findings also reveal that cross-sectional dependence exist across our sample countries. It implies that cross-sectional dependence and slope heterogeneity should be seriously considered in a cross-country investigation, particularly in a broad sample covering many countries with substantial differences. Ignoring this possibility may generate biased results and would produce misleading inference, which in turn leads to incorrect policy suggestions.

Nuclear energy is arguably one of the best sources for electricity generation that can meet these future needs and requirements. Even so, advances and improvements must be made for nuclear energy to be competitive in the future. The nuclear energy industry, governments and private operators must develop an approach for nuclear energy systems that minimizes high level waste inventories while at the same time maximizing fuel utilization to provide a secure energy source [11]. The policy implication is that measures adopted to mitigate the adverse effects of nuclear energy consumption may be taken without harming economic growth. However, these results should be interpreted with care, as they may not be sufficiently robust enough to support the inference that nuclear energy consumption plays a minor role in the economic growth of South Asian countries.

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